OCEAN EXPLORATION PARTNERSHIPS

OVER *the course of history, humankind has explored the oceans in search of natural resources, knowledge to support transportation and military ventures, and to learn more about the things that were in the vast unknown.*

More recently, exploration has laid the foundation for understanding the critical role that the oceans play in sustaining the biosphere. People's seemingly endless thirst for knowledge about the oceans' enormity, extremes in conditions, beauty, complexity, and association with human history can now be quenched with modern communications. While there have been, and still are, many reasons for ocean exploration, it is safe to say that ocean exploration is almost always accompanied by unanticipated discoveries, including knowledge that is invaluable for other purposes. Yet, ironically, most exploration to date has been relatively narrow in its purpose, and knowledge that does not serve the purpose of specific expeditions has not been shared.

Partnerships among all ocean exploration interests are needed if the full benefits of ocean exploration are to be realized. Partners should come from:

— ***Industries*** *seeking knowledge to support commercial activities such as fishing, energy and mineral extraction, pharmaceuticals, and other, as yet unknown, potentials.*

— ***Government agencies (both state and federal)*** *seeking knowledge about how the oceans function and to support their missions of national security, transportation, and the conservation and management of natural resources.*

— ***Academic institutions*** *concerned with ocean research.*

— ***Formal and informal educators*** *at all academic levels.*

— ***Mass media and media companies*** *seeking ways to inform and entertain the public.*

— ***Non governmental organizations*** *groups with a wide array of ocean interests, such as conservation, protection, education, entertainment, and research.*

Ocean exploration partners can play many different roles. Some of the partners will be the primary explorers. They will collect data from above, on and beneath the ocean's surface. Others will use the information collected by ocean exploration (e.g., for the design of future research, commercial enterprises, education, and conservation advocacy). It is also critical for users to be included in ocean exploration partnerships so that their interests are served. It must be recognized, however, that ocean exploration is not intended to be so tightly coupled with any particular user group's needs that the exploration endeavor loses the excitement of unanticipated discovery.

It is also important to recognize the vitality that a diversity of ideas will provide in the development of partnerships in ocean exploration. Some fear that ocean exploration will lead to ocean exploitation that is undesirable from their perspective. Others envision exploitation as the desired outcome. It is not necessary that all partners in ocean exploration share the same vision of the oceans for the future; however, ocean exploration should be neutral with respect to diverse views about how the oceans are used and conserved. If ocean exploration is successful in producing new information that excites and informs the public and officials with responsibility for the oceans, then the activity will likely lead to sound public policy choices that seek to balance diverse interests.

Ocean exploration requires both domestic and international partnerships. Most of the oceans are beyond the jurisdiction of any nation. Yet, the United States has a unique responsibility for the exploration of a larger ocean area (two million square kilometers) than any other nation.

After discovering the wreck of the *RMS Titanic* in 1985, Dr. Robert D. Ballard received thousands of letters from students around the world wanting to go with him on his next expedition.

The JASON Foundation for Education
an educational partnership

In order to bring the thrill of discovery to millions of students worldwide, Dr. Ballard founded the JASON Project, a year-round scientific expedition designed to excite and engage students in science and technology and to motivate and provide professional development for teachers. The JASON Project has been a leader in distance learning programs, and continues to expand its reach by adding more components each year. Funded by a combination of private industry and government, the program is now in its 12th year.

More information on the JASON Project is available at: **http://www.jason.org/**

Census of Marine Life: a Grand Challenge

The Census of Marine Life has been conceived as a bold program of discovery designed to capture the imagination of the American people. The challenge is to respond to important and fascinating questions about the amount, type and global distribution of marine life. These questions apply to past as well as current conditions, in order to prepare for anticipated future conditions. The planning for, and design of, the Census was a grassroots effort that involved the talents of many scientists from around the world, primarily supported by nongovernmental funds. The program they suggested includes the development of an Ocean Biogeographical Information System (OBIS), a research program to understand the history of marine animal populations and a plan for regional censuses to be taken to test technology and strategies. The Census program is now under way. This program will help fill in the gaps that currently exist in the area of marine biodiversity in order to help conserve endangered or overfished species. Without in-depth knowledge, species will be lost without people ever having known they existed. The sense of urgency surrounding this project is heightened by the expansion of fisheries into depths of a thousand meters or more in order to catch new species of fish. Many of these species are part of fragile ecosystems vulnerable to overfishing. Until the Census of Marine Life is complete, it will be extremely difficult to implement responsible management programs to address this situation.

More information on the Census of Marine Life can be found at **http://www.coml.org**

Characteristics of Ocean Exploration Partnerships

Ocean exploration is a broad endeavor, encompassing both vast geographic expanses and a wide range of disciplines (e.g., biology, geology, physical and chemical processes, archaeology). Many different technologies are used for ocean exploration. Thus, partnerships that are flexible in nature will best serve the goals of exploration. Nevertheless, some characteristics of these partnerships should be universal. They include:

— ***Partnership in planning***
An exploration partnership includes a shared plan with consensus building and maintenance. The plan should identify goals, strategies, responsibilities and access to information. All of the partners should stand behind the entire plan, rather than solely advocating their own self-interests.

— ***Multiple use of exploration platforms and sharing of other assets***
The assets needed for exploration include ships, submersibles, observatories, airplanes, satellites, and databases. Many types of sensors and collection devices are used, and often, they can collect multiple types of information on the same mission. A successful partnership for ocean exploration will take advantage of the opportunity to gain as much knowledge as possible from its assets.

— ***Interdisciplinary partnerships***
It will be common for partners in ocean exploration to have multiple interests. As noted above, the assets for ocean exploration may be capable of collecting multiple types of information. Thus, ocean exploration partnerships should be interdisciplinary.

— ***Information sharing***
Information derived from ocean exploration will be accessible in the public domain so that it can achieve its full value, including the intangible value of informing the public.

— ***Partnerships in education***
Partnerships with this group are essential. One mechanism to enhance this partnership would be the creation of an Ocean Corps of students of all ages who dedicate time and energy to specific expeditions. Members of the Ocean Corps would assist in ocean exploration and communicate their experiences to the education community. They will also communicate — often in real-time — to others through the Web and other media. This would provide a unique foundation for school-to-career and public service learning opportunities.

Arrangements for Partnerships

Many existing organizations are capable of planning and / or managing ocean exploration. These include domestic and international, and governmental and nongovernmental organizations. Whenever practicable, existing organizations should be used to avoid creating unnecessary bureaucracy and expenses. In some cases, new arrangements may be necessary to oversee a partnership for exploration, but these should have a finite life span to match the duration of the mission(s) undertaken by the partnership.

While existing organizations will play a critical role in the Program, a Forum must be established to bring together all stakeholders to exchange views, promote communication and networking, and continually inform the participants. Such a Forum will be well suited to identify stakeholders' opportunities and interests as a precursor to forming partnerships.

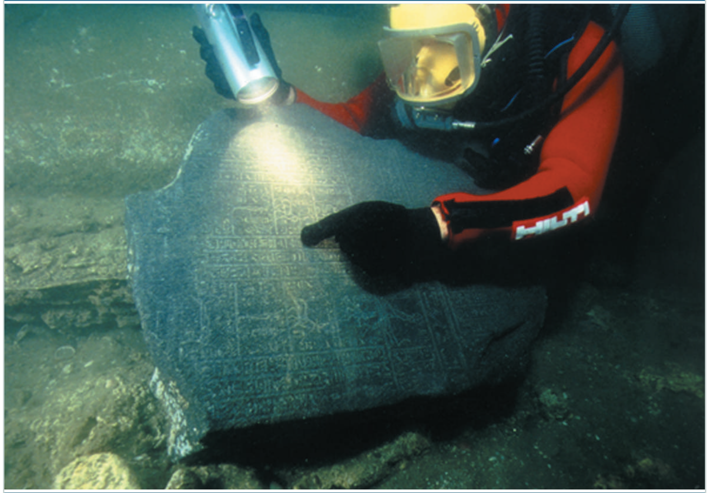
Vision for Coordinated Federal Ocean Exploration Program

In creating the framework for governing new activities in ocean exploration, the Panel advocates the following steps be taken.

— ***The President should instruct the White House Science Advisor and appropriate Cabinet officials to ensure the successful initiation and implementation of a national Ocean Exploration Program. The Panel also recommends instituting a follow-on group to maintain momentum and provide more detailed planning.***

The European Institute for Underwater Archaeology (IEASM) is a privately funded, multilevel partnership for international underwater archaeology, carried out in collaboration with national governments, museums, and navies of the host countries. Products of the partnership include traveling and permanent museum exhibitions, extensive publications of archaeological reports, popularized high-quality publications for public consumption, film documentaries, educational CDs for students and extensive websites published during field projects. IEASM currently has projects in:

EUROPEAN INSTITUTE FOR



UNDERWATER ARCHAEOLOGY

EGYPT Projects include Alexandria, the Bay of Abou Kir, Napoleon's fleet, and ongoing magnetometer and side-scan surveys.

PHILIPPINES Projects include the San Diego, five Chinese shipwrecks ranging from the 12th to the 16th centuries, and two 18th century East India Company shipwrecks.

CUBA Project consists of extensive surveying and searching for a 16th century shipwreck.

http://www.franckgoddio.org

ACADEMIA and NOAA

The National Undersea Research Program (NURP) is one example of a NOAA program that works directly with academia to carry out its research and exploration. With a mission of providing the expertise and technologies to place scientists underwater, either in person or remotely this program works through a network of regional centers operated by universities or private foundations. Each Center carries out a competitive, peer-reviewed science program supporting the undersea research needs of NOAA and the nation. You can find NURP's web site at:

http://www.nurp.noaa.gov

NOPP: the National Oceanographic Partnership Program

NOPP was established in 1997 by the National Oceanographic Partnership Act to integrate national efforts in ocean science and technology, including both research and education. NOPP's goal is to promote broad national needs by enabling coordinated national investments in ocean research and education. NOPP shares resources, data, intellect and experience between its partners in government, academia, industry, and other members of the ocean sciences community. Leadership is provided by the National Ocean Research Advisory Panel, which includes representatives from the National Academies of Science and Engineering, the Institute of Medicine, ocean industries, state governments and academia. The Partnership was formed by Congress to provide a mechanism for effective coordination of complex studies of the ocean and long-term monitoring between government agencies and the other partners.

For more information, log on to the NOPP web site at:

http://core.cast.msstate.edu/NOPPpg1.html

— ***Institutional arrangements should clearly identify and rely on existing interagency mechanisms to ensure federal cooperation, coordination, and efficient use of resources and effectiveness.***

— ***A single lead agency should be designated as in charge and accountable for the program and its budget. Leadership should be assigned to the agency most likely to champion a broad spirit of exploration and least likely to divert ocean exploration toward narrower, mission-oriented activities.***

— ***New support resources and staffing should be allocated to implement and sustain the program.***

— ***The federal Ocean Exploration Program must identify and promote processes to establish effective partnerships and the involvement of stakeholders in all phases of program development and implementation.***

— ***Accountability should be articulated in advance through benchmarks and performance measures to evaluate outcomes. The benchmarks should be appropriate for ocean exploration, and measure the degree to which the Program is following the desired characteristics and meeting the challenges described in the first chapter of this report. The lead agency should, every three years, report on progress toward meeting performance goals, and review funding needs to the President and Congress.***

— ***Program participants should agree on criteria for the selection of projects to assure high scientific quality and visionary oversight.***

— ***The Program should include a global perspective promoting international partnerships.***

— ***The Program should be recognized as requiring implementation over an extended period of time (e.g., several decades).***

— ***The Program should be implemented in a manner that allows public involvement and oversight.***

IRISH SEABED SURVEY REVEALS RICHES

A seven-year project to map the seabed off Ireland's coastline is under way and already delivering results. Ireland's seabed survey has mapped nearly 18 percent of the territory and researchers say they hope to have the first definitive results by next summer. Potential gas reserves associated with carbonate mounds have been identified in preliminary findings, which were released at a Geological Survey of Ireland (GSI) seminar in Dublin last month. According to a spokesman, two ships have been dedicated to the seven-year survey by the agency, the 79.25-meter *R/V Bligh*, a former British navy ship, and the 68-meter *R/V Siren*. Both are owned and run by Global Ocean Technologies Ltd. (Gotech), which was contracted by the GSI as manager of the initiative. The Waterford-based company, which has been involved in seabed projects around the world, believes that this is the most ambitious survey of its type. Ireland has one of the largest offshore exclusive economic zones in Europe, some 850,000 square kilometers. Presenting an overview of progress to date, Gotech's Noel Hanley and the GSI team of Deepak Inamdar, Helen Gwinnutt, Mick Geoghegan, and Garrett Duffy reported that 72,563 square kilometers had been mapped. The main focus initially has been on Zone 3, the more distant and deeper part of the seabed. The multibeam sonar employed, Kongsberg Simrad's EM120, proved to be very successful, according to Hanley. "Its area of coverage is five times as wide as the water depth. It can penetrate the sediment and is fitted with a yaw correction to stabilize images in bad weather", he noted. The high-resolution data collected include an image of the wreck of the *Lusitania*. The wreck has been lying in 100 meters of water 18 kilometers south of the Old Head of Kinsale since its sinking by a first World War torpedo in 1915 with the loss of 1,200 lives. A hydrographic survey ship using echosounders in 1937 first located the wreck. The *Bligh* and *Siren* are also using sub-bottom profiling to detect rocks, gas, and other minerals. They are also fitted with magnetometers and gravity meters. Some 15 major canyons on the side of the Rockall trough were identified in earlier work, and the GSI's reconnaissance survey of the Irish continental shelf and shelf edge in 1996 is regarded as essential groundwork for this initiative.

RECOMMENDATIONS

The President of the United States should instruct the White House Science Advisor and appropriate Cabinet officials to design the management structure for this program. Elements of governance should include:

— ***Designating a lead agency to be in charge of the Program and accountable for its success using benchmarks appropriate for ocean exploration, such as the number of new discoveries, dissemination of data, and the impact of educational outreach.***

— ***Using existing interagency mechanisms to ensure federal cooperation among agencies.***

— ***Establishing an Ocean Exploration Forum to encourage partnerships and promote communication among commercial, academic, private, non governmental organizations and government stakeholders.***

TECHNOLOGY REQUIRED FOR OCEAN EXPLORATION

BECAUSE *the ocean contains the most hostile, dynamic, and complex environments on Earth, the technologies used to unlock its secrets must be innovative, robust, and capable of a broad range of measurements, over time spans from seconds to years.*

These instruments will often be required to operate in chemically caustic and high-pressure conditions, and to transmit the collected data back to shore-based laboratories for further analysis and real-time interaction with seafloor or oceanographic experiments. Such will be the demanding nature of ocean exploration in the coming century and beyond. The past 40 years of outer space exploration has prepared us for what will be the ultimate technological challenge facing the human species — the exploration of the Earth's oceans.

The past half-century of oceanographic research has demonstrated that the oceans and seafloor hold the keys to understanding many of the processes responsible for shaping our planet. The Earth's ocean floor contains the most accurate and complete record of geologic and tectonic history for the past 200 million years. For the past 30 years, the exploration and study of seafloor terrain, and the unraveling of plate boundary processes within the paradigm of seafloor spreading have revolutionized earth and ocean sciences. This new view of how the Earth works has provided a quantitative context for mineral exploration, land utilization and earthquake hazard assessment, as well as conceptual models that scientists use to understand the structure and morphology of other planets in our solar system. Much of this new knowledge stems from studying the seafloor — its morphology, geophysical structure and characteristics, and the chemical composition of the rocks of which it is comprised. Similarly, the discovery of deep-sea hydrothermal vents at the mid-ocean ridge, and the chemosynthetic-based animal communities that inhabit the vents have revolutionized biological sciences. This discovery has also provided a quantitative context for understanding global ocean chemical processes, and suggests modern analogs for both the origin of life on Earth and extraterrestrial life. Intimately

FLOATS & GLIDERS

Satellite-based sensors have provided a remarkable view of nearly the entire global ocean surface at a spatial resolution as small as 1 to 10 kilometers. They have revealed a complexity of patterns that most likely extends into the deeper ocean, but that cannot be measured with ship deployed samplers and sensors. Efforts are being made to improve our ability to image the horizontal scales of the ocean below the sea surface. The Argo program is an international effort that seeks to deploy thousands of pop-up floats throughout the world ocean that will record ocean properties from the sea surface to their "parking" depth and transmit the data back to shore via satellite links. An armada of such floats spread over the ocean will monitor the temperature, salinity and oxygen structure of the ocean. Other parameters, e.g., shear, may also be measured. Sensors to directly measure other parameters from the floats, such as nutrients and tracer elements, need to be perfected. It is anticipated that soon, CO_2 concentrations and the DNA of a number of plankton species will also be able to be determined from autonomous underwater vehicles. A new generation of gliding vehicles is yet to be developed. These instruments could descend and ascend as floats, but more important, they could use the position fixes obtained when they surface to navigate along a prescribed track. Gliders will be able to traverse the ocean along the same track to provide high-resolution, repeat sections across oceanographic fronts and currents.

& AUVs

Over the past decade, Autonomous Underwater Vehicle (AUV) technology has advanced to the point where a variety of AUVs have begun to make unique oceanographic measurements. The original concept of the AUV called for it to perform surveys similar to those done with human-occupied submersibles or tethered vehicles, though at a lower cost and with less dependence on support vessels. These capabilities have been proven. AUVs have been shown to make many types of measurements better than other existing devices, especially those that require repeated time-series measurements in hostile weather environments. The new generation of AUVs are capable of reliably determining their position, using the computed position to automatically follow preprogrammed tracks, and following the bottom using measurements from an array of acoustic sensors. With a focused development program, AUVs will soon be capable of deploying a wide range of mapping and sampling systems to any position in the water column. Future programs of synoptic ocean exploration will rely on fleets of AUVs dispersed throughout large areas of the oceans. These AUVs will begin to record data sets rich in both spatial and temporal resolution of complex oceanographic processes. Key technological challenges related to AUV development entail increasing their endurance through innovative power systems, and improving global navigation schemes to permit unattended operation in remote areas over long periods of time.

tied to these research themes is the study of physical and chemical oceanography which has resulted in unprecedented perspectives on the processes which drive climate and climate change on our planet. These are but a few of the many examples of how basic oceanographic research has revolutionized our understanding of Earth's history and provided a glimpse at the diversity of scientific frontiers still awaiting exploration.

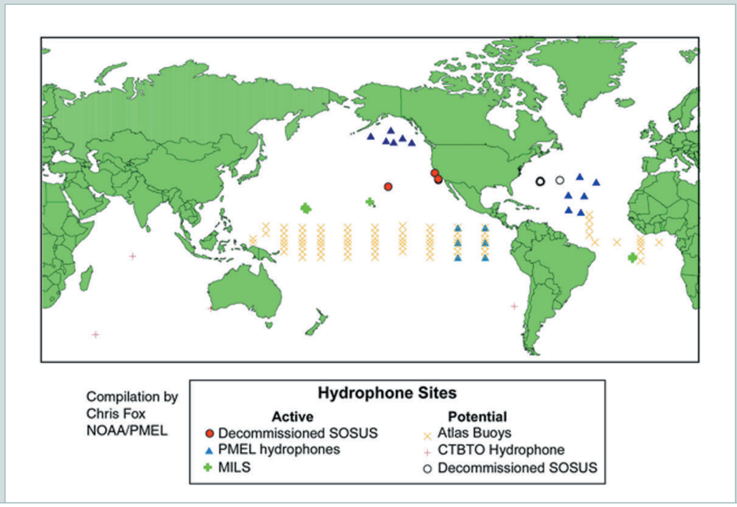
These breakthroughs resulted from the intensive exploration that typified oceanographic expeditions from the 1950s through the 1970s and focused the development of oceanographic technology and instrumentation that facilitated discoveries on many disciplinary levels. Significant among these enabling technologies were satellite communication, global positioning, microchip technology, the widespread development of computers that could be taken into the field, and increasingly sophisticated geophysical and acoustic modeling and imaging techniques.

In addition, traditional 19th and early 20th century methods for imaging the seafloor from the beach to the abyss, and sensing chemical and

EXPLORING the GLOBAL OCEAN

Using passive underwater acoustics to listen to the ocean is an ideal way to monitor oceanographic and tectonic phenomena on a global basis. The presence of an underwater sound channel at ~1000 m in the ocean allows the propagation of low-frequency acoustic energy over ocean-basin scales. Examples of significant discoveries already made using dual-use U.S. real-time hydrophone arrays include the detection of deep-sea volcanic eruptions and the tracing of migratory paths of the blue whale. These listening efforts initially depended on the U.S. Navy Sound Surveillance System (SOSUS). However, other low-cost, portable monitoring systems and devices have been developed and deployed in several ocean areas. Government agency partnerships to promote further development and use of this technology are already in place with NOAA, various Navy commands, academic institutions, and international partners, including the NOPP Ocean Acoustic Observatory Federation. The goal of sensing the "pulse" of the Earth and oceans via a global network of passive acoustic monitors is achievable with appropriate planning and funding, and will result in dramatic new views of the processes and events that shape our planet and its ocean.

USING PASSIVE UNDERWATER ACOUSTICS



biological processes at all levels in the ocean, were supplanted by submersible vehicles of various types, remote-sensing instruments, and sophisticated acoustic systems designed to resolve a wide spatial range of ocean floor and oceanographic features and processes.

Technology will enable the next generation of ocean exploration, but if the United States is to be a leader in this area, we must make a commitment to recapitalize our explorers with the very best technology. New instruments will need to be developed, and existing systems and data will need to be upgraded and fully utilized. In addition, new systems of telecommunication and global positioning infrastructure will be required to collect data from remote parts of the global ocean, especially the polar regions and the southern ocean.

Taking the Cognitive Brain and Spirit into the Ocean

Since ancient times, the human spirit has sought to understand the mysteries of the ocean. For the past 40 years, this need has been met by the ability to take the unique human visual and cognitive abilities into the ocean and down to the seafloor to make observations and facilitate measurements in submersible vehicles. Various types of submersibles were initially developed to support strategic naval operations of several nations. As a result of this effort, in 1963, the deep diving submersible *Alvin* was constructed by the United States. *Alvin* is still is use today as part of the National Deep Submergence Facility (NDSF) funded by the Navy, the NSF, and NOAA, and operated by the Woods Hole Oceanographic Institution (WHOI). It provides routine access to ocean depths as great as 4,500 meters for one pilot and two scientists or engineers at a time. Capable of reaching about 60% of the seafloor, *Alvin* usually dives for 8-9 hours per day and spends about 5 hours a day traversing the seafloor, making observations, sampling, and taking high-resolution still and video photography. Throughout its more than 35-year history, *Alvin* has completed over 3,600 dives (more than any other submersible of its type), and participated in making several key discoveries. These discoveries include mapping the structure of the mid-ocean ridge (MOR), transform faults and submarine canyons, discovering hydrothermal vents, and collecting samples and making time-series measurements of biological communities at the hydrothermal vents. In 1991, scientists in *Alvin* were the first to witness the vast biological repercussions of eruptions at the MOR axis, which provided the first hint that an enormous subsurface biosphere exists in the crust of the Earth on the seafloor.

Despite these significant successes and recent improvements to *Alvin*'s operational systems, deep submergence technology and vehicle system capability in the United States now lag behind Japan and France. These countries have government / industry collaborations, that have been well capitalized for over a decade and that continue to be supported at annual funding levels that vastly exceed U.S. spending on the NDSF and related diving capabilities. The latest French and Japanese submersibles can dive to 6,000 m and 6,500 m, respectively, depths that allow scientists using those vehicles to access more than 98% of the global seafloor. The Japanese deep-diving remotely operated vehicle, *Kaiko*, is capable of reaching virtually all ocean depths. Given these facts, the U.S. needs to rapidly increase the level of its capitalization and construction of new facilities available to ocean explorers.

Enhanced data transmission is needed from all levels in the ocean to the surface and from there to shore-based laboratories. This will require the development of an effective global data communications system and a strategy to bring the fruits of exploration not only to scientists, but also to the public and students at all levels, so that the broadest spectrum of people can benefit from 21st century ocean exploration.

Development of state-of-the-art sensors and deployment strategies will also prove essential for multidisciplinary, in-situ, and remote-sensing measurements of biological, chemical, physical, and geological processes throughout the ocean. This must include real-time remote-sensing of the global ocean via acoustic and seismic monitoring and other means in order to calibrate and study the "pulse" of the Earth and life in the oceans. The construction of new, innovative deep ocean vehicles and ocean-floor observing systems will be needed to facilitate exploration. The types of systems that will be required include human-occupied submersibles, remotely operated vehicles (ROVs), Autonomous Underwater Vehicles (AUVs), mobile observatories for seafloor and oceanographic measurements, and vehicle systems capable of facilitating marine archeological exploration and excavation.

RECOMMENDATIONS

— ***Undertake development of underwater platforms, communication systems, navigation, and a wide range of sensors, including the capitalization of major new assets for ocean exploration, to regain U.S. leadership in marine research technology.***

Measurements of trace chemicals in saltwater and sediments on the seafloor are required to understand a wide range of exchange processes that affect ocean chemistry and biology. One system currently under development by Professor George Luther at the University of Delaware will monitor chemical reactions in environments ranging from microbial mats to sediments to hydrothermal vents. A solid-state, gold-amalgam voltammetric microelectrode is the key component of part of this portable electrochemical system. It can "sniff out" trace chemicals that exist in extreme environments. The new microelectrode can measure dissolved oxygen, sulfide, iodide, Fe(II), Mn(II), and FeS. Each chemical species, if present, produces a current that can be detected in one potential scan. This type of technology represents the vanguard of microsensors that will be capable of detecting and quantifying small changes in chemistry in the myriad of chemical and biological processes occurring in the ocean and on the seafloor.

SOLID STATE VOLTAMMETRY SMELLING UNDERWATER